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PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Treatment of Plastic Materials

We, WELDING ENGINEERS, INC., a Corporation organized and existing under the Laws of the State of Delaware, United States of America, whose post office address is Norristown, Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the treatment of plastic materials.

It relates especially to the treatment in their plastic range of thermosetting materials such as phenol-formaldehyde and urea-formaldehyde.

It also relates to the treatment of thermoplastic materials which are to be handled with particular care to avoid decomposition from overheating or overworking.

In the past, thermosetting resins being used with fillers, lubricants, pigments or dyes, catalysts, etc., mixed together to prepare a moulding powder granule have usually been treated by batch method on such a device as a horizontal two roll mill. Typical disadvantages of this method are that all the material in a batch does not get the same treatment, since some of the material will be removed from the mill as finished an appreciable time before other portions which therefore will be subjected to more heating and working; also some types of mixes are not readily processed on a mill with high cost or poor product quality resulting.

An object of the invention is to provide a continuous method of processing thermoplastic materials and especially thermosetting materials in their plastic range prior to their curing or polymerizing.

Another object of this invention is to provide a method assuring improved quality in materials processed through it over the quality obtained by other commercial means.

A further object of this invention is to provide a processing means for the treating of plastic materials that will give a product in a more desirable physical form than can normally be obtained by other means.

Additional objects will be made clear in the following specification.

The device is illustrated in the attached drawings in which:—

Fig. 1 is a horizontal sectional view showing the portion of an apparatus that does the treating.

Fig. 2 is a vertical section along line 2—2 of Figure 1 with the screw worm shown in full side view.

Fig. 3 is a front view of the die.

Fig. 4 is a transverse section along line 4—4 of Fig. 1.

Fig. 5 is a transverse section at line 5—5 of Figure 1.

Fig. 6 shows alternate design of the rear portion of the worm.

Fig. 7 shows alternate design of the center portion of the worms

Fig. 8 is an enlarged sectional view of a modification of the die.

Fig. 9 is a fragmentary view of the die and end of the flight.

Fig. 10 is a sectional view of a further modification; and

Fig. 11 is another type of die and showing a modified worm used with it.

In preparing the material so that it will be suitable for processing, it is usually desirable to have a uniform and fine dispersion of the various materials that make up the mix. For instance a high intensity centrifugal mixer does a good job of breaking up agglomerates of filler or some other materials, resulting in a uniform mix. If the liquid ingredients are present in sufficiently large proportion to make a wet mass, other mixing methods must be used.

In the thermosetting materials suitable for processing on this equipment such as phenol-formaldehyde, urea-formaldehyde, melamines, etc., as the temperature is raised, the cure or polymerization takes place, converting the

resin into a hard substance that will not soften from the heat. This polymerization is intended to take place in the finished mold or other device when the material is in its final form. If too much cure takes place before the material reaches its final form, then the end product will not develop its full strength and desirable physical properties. For this reason, the degree of heat, plasticizing, and cure must be carefully controlled in all portions of the machine.

There is a wide variety of materials currently used in industry capable of being processed through this equipment. They vary as to softening point, the temperature span between softening and curing, plastic flow properties, time of curing and so forth. In many cases, jacket temperatures, worm speeds, dies and other operating conditions must be varied in treating these materials. Although the worms herein described are of a design capable of processing a variety of materials, it is nevertheless necessary to use worms of different designs to get satisfactory results on materials of widely different properties.

In the embodiment shown in Figures 1 and 2, the material to be treated is introduced to the two oppositely rotating worms 10, 11 through the hooper 12, and opening 13, in the casing structure 14. The worms 10 and 11 rotate toward each other, when viewed from above in the cylindrically surfaced parallel bores 16, 17, respectively. The cylindrical bores 16, 17 are side by side and have an opening between them to form a longitudinally extending slot 20, interconnecting the bores.

The worms 10, 11 are comprised of the stems 22, 23, respectively and helices or flights 24, 26, in the feed portion. The resistor portion 28, 29 is comprised of stems 57, 58 and flights 55, 56, respectively and in the extrusion portion stems 25, 27 and flights 30, 31 respectively. The flights of worm 10 are oppositely pitched to the flights of worm 11 and will advance material from the hopper to the die when rotated as described above.

The casing is equipped for circulation of a heat transfer medium through separate jacket zones 33, 34, 35, 36 which are separated by partitions as at 37, 38. Inside the inner walls 39, 40 of the jacket are the liners 42, 43 forming the bores encasing the worms 10, 11, respectively. The temperature of the heat-transfer medium circulated through the compartments are measured by the thermometers 46, 47, 48 and 49. The compartments form independent zones which are adjusted to the desired temperature. The liners 42, 43 forming the cylindrical surfaces may be replaceable and are usually made from hard faced materials to resist abrasion. Corrosion resistant materials may be used when required

The worm 11 is shorter than the worm 10 and the material in the bore 17 is transferred to the bore 16 through the slot 20 at the end of the worm 11. A block 50, provided at the end of the bore 17, has a conical recess 51 for receiving the tapered end 52 of the worm 11 and a side passage 53 in the wall of the recess 51 to connect the recess with the bore 16. The material is continuously passed from bore 17 to bore 16 and does not collect and stagnate. The worm 10 then forces all of the material through the die plate 18.

The worms 10 and 11 fit into the bores 16 and 17, respectively with a close running clearance and are driven at the ends 54, 55.

In this embodiment, the stems 22, 23 are of a constant diameter slightly larger than one-half the diameter of the bores 16, 17 while the 360° spacing " A " between the flight sections, i.e., the pitch of the helix, progressively diminishes in the direction of flow of the material from the hopper opening 13 toward the resistor portion. In a machine having a 2" diameter worm, a $2\,^1/_2''$ pitch at the hopper reducing to a $1\,^3/_4''$ pitch immediately prior to the resistor portion 28, 29, is satisfactory. The flights 24, 26, terminate to leave an annular space " B ", permitting free passage of material into the resistor portion. Alternatively, and as shown in Figure 6, the diameter of the stem increases progressively in the direction of flow of material.

The intermediate resistor portions 28, 29, have flights 55, 56, and stem portions 57, 58, which at least over a portion of their length are substantially larger in diameter than the stems 22, 23 of worms 10, 11. The running clearance or free volume " C " between the stem and the liner is considerable restricted, and is constant for the first few turns of the flight. In the last half turn of a complete flight, the diameter of the stem portion of the resistor is further increased to provide a further reduced clearance " D ", the diameter of the stem portion of the resistor thus increasing throughout the length thereof in the direction of flow of material. In a machine having 2" diameter bores, a pitch of about .8" and a depth of $^1/_4''$ at space " C " is satisfactory with a final decrease in depth to about $^1/_{16}''$ and an axial length of $^5/_8''$ at space " D ". This provides a minimum depth of approximately $^1/_{30}$ of the diameter of the bore. As can be seen the free flight area at this point can be expressed in terms of the diameter of the bore thus: $\frac{D^2}{104}$. This area can be increased or decreased in a range of $\frac{D^2}{150}$ to $\frac{D^2}{75}$. If this area is increased till it reaches $\frac{D^2}{40}$ its effectiveness in producing working of the material in the previous portion of the worms will practically disappear.

In the extrusion portion, the stem diameter is decreased to slightly over one-half the diameter of the bore and flight 30 is commonly of a constant pitch equal to the outside diameter of the worm. Flight 31 can be similar to flight 30 in pitch or of some other design calculated to pass the material across into the flights of the extrusion portion of worm 10. The extrusion portion, i.e., flight 30, of worm 10 has a helix of less pitch than the minimum pitch of the first feed flights 24, 26, and may be varied in design such as by the use of a decreasing pitch of the helix or an increasing stem diameter where the nature of the process requires.

The material to be processed is seized by the flights 24, 26 of the feed portions of worms 10, 11, and advances along the bores 16, 17. The resistor portions 28, 29, create a back pressure so that material is worked under pressure from the flights. The jackets 33, 34, are used to control the surface temperature of liners 42 and 43, thus influencing the temperature of the material being treated and the character of the mechanical working given the material by the worms. As the material is forced through the resistor portions 28, 29, it must pass through the small spaces "D" before escaping from these portions of the worms. In the typical embodiment shown the free volume of an axial section in the worm flight at this point is in the order of one twenty-fifth as great as the corresponding volume between flights 24 or flights 26 in the vicinity of the hopper opening 13, and this results in a tendency for the worm to exert considerable compression on the material with consequent shearing, heating, and mixing of the material as pressure is generated on it and as it issues through restricted space "D" to be passed into an area of reduced pressure beyond. It is obvious from this description that the feed portion and resistor portion could be conceived of as a continuous worm without interrupting the helical flight and if the material issued through a small space corresponding to "D" and into an extrusion portion it would not depart from the nature of this invention. The volatiles that may be present in the material can then be released and escape through a vent 60, in the casing which is forward of the resistor portion. The vent may open into the atmosphere or a cover 61 may seal the vent and a suction or vacuum be applied to the opening 62, in the cover to aid in the devolatilization of the material while a gauge may be applied at opening 90 to aid in maintaining the desired level of vacuum. If required, the vent 60, may be eliminated and casing and liners made solid. Heat transfer medium circulating in zone 35 controls the liner temperature in this portion.

As the material issues from the resistor portion, it is advanced by flights 30, 31, of worm 10, 11. The material in worm 11 moves through the slot 20 and along the surface 53 and into worm 10. Worm 10 advances the material along bore 16 and extrudes it through the die 18. The die is equipped with multiple orifices 19, through which the material passes and is formed into rods. If desired, the material can be cut into pellets as it issues through the die holes. As the extrusion portion of worm 10 forces the material through the die, considerable pressure is generated with consequent mixing and heating of the material. The design of the die influences the intensity of this action and must be such that the total heating and shearing that takes place on the material in the feed, resistor, and extrusion portions, including the vapor extraction, gives the correct amount of mixing and partial cure needed in the product. Smaller holes, and a greater distance through the holes makes for greater resistance and more mechanical work on the material. A die with closely spaced holes of .145" diameter and $^{3}/_{16}$" through the hole has been found to be satisfactory. The jacket 36 is often kept at a low temperature of from 100° F. to 150° F. to help cool the material in this section.

In Figs. 1, 2 and 8 the second flight of the worm terminates at the die with an edge spaced a distance "E" from the inner face of the die. The tip of the worm approaching the edge should be designed to give the maximum wedging action to push material through the die holes and the flat edge 88 resulting from a transverse cut as shown in Figure 8 should be reduced to the smallest practical area. With such an arrangement, material can be extruded with a smaller temperature rise than would occur otherwise. The distance "E" from the tip of the worm to the die should be very close, just sufficient to give a running clearance. As the spacing is increased the wedging action of the worm tip tends to lessen and approaching 0.1" and above it loses its effectiveness. Wider spacing can therefore be used if additional heat and working are desired.

In Figs. 8 and 9 the end of the second flight worm and die are shown in detail. The worm 77 has an edge 88 spaced from the inner face of the die 78 a distance so that the edge 88 does not touch the surface. The clearance or distance "E" between the edge and the inner face of the die is at a minimum. It is preferable that the spacing should be not more than $^{1}/_{8}$ of an inch from the inner face. The surface 90 of the worm approaches the edge 88 and turns parallel to the die face to form the space "E" between the end of the worm and the inner face of the die that is wedge shaped. This is illustrated in Fig. 9 where the surface 90 curves around to be parallel to the die. The material is carried down in front of the surface 90 and squeezed out through the openings. As above noted

the space "E" is preferably not greater than one-eighth of an inch. As this wedging action supplying the surface pressure decreases the extruding action depends increasingly on the pressure supplied by the worm flights with consequent tendency to working and heating of the material to increase the curing of the material.

This wedging action concentrates the working and heating of the material to this localized area at the die and to one or two front flights of the worm and considerably reduces the working and heating of the material that takes place in the worm flight between the vent 60 and the die. This gives the necessary control with relatively quick curing materials.

In Fig. 6, another preferred form of the feed portion of the worms is shown tending to lesser heating and working of the material. The oppositely rotating worms 63, 64, have flights 65, 66 and stems 67, 68. The pitch of the flights 65, 66, is constant and is approximately equal to their outside diameter and the diameter of the stems 67, 68, gradually increases from the feed opening in the direction of flow of the material. The free volume "F" between the stem and the wall of the liner 42, decreases in the direction of travel of the material.

In Fig. 7 is shown another embodiment of the resisting portion of worms 10, 11. Resistor portions 70, 71 have flights 74, 75 with a pitch of from one-fourth to one-half their outside diameter and stems 72, 73, increasing in diameter in the direction of flow of the material. In a 2″ diameter worm, a clearance $^1/_4$″ at the deep end, decreasing to $^1/_{16}$″ at the shallow end is satisfactory. This type of worm gives more working to the material than those shown in the resistor portion in Fig. 1.

In Fig. 8 is shown another embodiment of the die. The bore 76 and the worm 77, are flared at the end adjacent to the die 78. This flare of the worms and bore behind the die permits the use of more holes in the die, thus, facilitating the flow of material through the die and reducing the back pressure created by the die. Therefore, less pressure is needed to force the material through the die.

The die holes have a short, cylindrical portion 79, with a length approximately equal to their diameter, which is followed by a portion 80, that tapers to a larger diameter in the direction of flow of the material. A cylindrical portion .120″ in diameter that flares to .145″ diameter for a total length of $^5/_8$″ through the holes is satisfactory, the larger diameter being thus slightly less than $^1/_4$ greater than that of the cylindrical portion. The length of the tapered portion is preferably at least one-half of the length through the holes. This design of the die offers less resistance to the flow of the material than a straight hole, even if the straight hole were of the larger diameter of .145″. It is also satisfactory to continue the taper all the way through the die, eliminating the short cylindrical section, and the diameter of each hole at the outer face of the die must not be more than $^1/_4$ greater than the diameter of the hole at the inner face of the die.

In Fig. 11 is shown another embodiment of the die hole in which the straight cylindrical portion is followed by a shoulder 81 and the hole is outwardly flared as at 82 beyond the shoulder.

In Fig. 10 is shown an alternate design of die and worm used for the production of a continuous ribbon of material. The die of Fig. 10 is provided with a conical recess 83, communicating at its larger end with the bore 16 and from the smaller end of which a slot 84, leads. The worm flights 85, are tapered down at the same angle as the wall of the recess 83 to form a tapered tip having a close clearance of the order of $^1/_{32}$″ to $^1/_{16}$″ therewith and overlapping the intersection of the slot 84 with the recess 83. The material travels through the recess 83, and stagnation is prevented because of the close clearance of the flights 85. It then moves through the slot 84, and issues as a continuous ribbon. Heaters can be applied to the outer surfaces 86, 87, of the die, if desired. In many cases the quality of the strip produced is superior to products made by other methods since it can be formed at low pressures and temperatures, is continuous and uniform quality, and in the processing of fibrous filled materials seems to eliminate the formation of planes of cleavage where fibres are not interlaced that occurs in some other processes.

In the thermosetting materials suitable for processing such as phenol-formaldehyde, urea-formaldehyde, melamines, etc., after the temperature is raised, the cure or polymerization of the material takes place, progressively converting the resin into a hard substance that will not soften on application of heat. Most of this polymerization is intended to take place in the finished mould or other device when the material is finally formed. This final polymerization should not take place before the material has reached the final stage of moulding. The greater the advance of the cure of the resin in the preparation process the harder the flow of the material in the final molding step. Too much polymerization in the processing machines prior to the introduction to the final molds will result in the end product not having its full strength and desirable physical properties. The above described machine handles the preliminary processing and partial polymerization and permits the careful control of the degree of heating plasticizing and polymerization which is necessary for the production of the proper end product.

Since the heat to which the material is sub-

jected is important, temperature-circulating medium is carefully controlled and measurement taken by the thermometers. Heat is not only attained from the circulating medium in the compartments 33, 34, 35 and 36 if required, but is also generated from the working of the material by the flights of the worms. The circulating medium in the compartments around the bores may thus absorb heat from the material in order to maintain it at its proper temperature. The worms may also be cored for circulation of heat transfer medium by means known in the art. This heating and plasticizing take place gradually through the feed portion of the flights 24, 26 and the resistor portion 28, 29 of the intermediate portion of the worms 10, 11 and is held below the point where too much cure would occur. As the material passes from the flights 55, 56, into the flights 30, 31, the pressure created by the restriction of the clearance "D" and the reduced pitch of the flights 55, 56, is reduced and the volatiles escape from the material. The material is further worked by the flights 30, 31.

As previously mentioned, the vent 60, may be sealed and a vacuum applied to remove the volatiles from material. This vent not only removes the volatiles from the material but sometimes produces other effects on the operation. The reduced pressure correspondingly increases the forward pressure applied by the preceding flights on the worms and thereby increases the pressure on the material. The vacuum not only withdraws the volatiles and gases from the material at the vent, but its effect also reaches back into the material being carried by the first flights 24, 26 and flights 55, 56. Since the material in this portion of the worms is sometimes only partially plasticized, it is not fully densified and the porosity of the material provides channels through which air and vapors pass. The vacuum pulls the air and vapors through the material which is moving from the hopper and advancing towards the vent. This drawing of the vapors in a forward direction assists in the drawing forward of the material and its densification which creates a better extrusion condition. This forward movement of the air provides a considerable improvement over the operation of the machine occurring when the air on being pressed out is forced to move backwards toward the hopper in a direction opposite to the movement of the material, and a higher throughput is effected. This effect is particularly noticeable when the material introduced to the hopper is of a fluffy character. With some materials, the application of vacuum does not increase the throughput.

Different modifications of the machine are better suited to the processing of certain material than others. The embodiment shown in Fig. 7 of the resistor portion having the gradual reduction in the running clearance between the intermediate portion and the liner is preferred in the working of some materials. A cylindrical or conical member also could be used with some materials.

The feed worm shown in Fig. 6 with the worm having a constant pitch and an increasing stem diameter is preferred for the phenol-formaldehydes when used with the restrictor portion shown in Fig. 1.

What we claim is:—

1. A material treating apparatus for mixing and processing thermosetting plastic materials, comprising a casing having a pair of parallel cylindrical bores with a common wall portion and a longitudinally extending opening therethrough, a feed opening at one end of said casing, and an extrusion opening at the other end of the casing, a pair of oppositely rotatable helical feed members extending respectively from the feed opening through the said bores for advancing the material through the casing, one of the said feed members extending to the extrusion opening and the other feed member together with the encasing bore thereof, terminating at a distance from the said other end of the casing, each of the said feed members having forward feeding helices supported upon a stem and extending throughout the length of the respective bore and including a forward feeding resistor intermediate the length of the member and co-operating with the wall of the bore to provide a restricted passage for the flow of material, having a cross sectional area not greater than $^{1}/_{40}$ of the square of the bore diameter.

2. Apparatus according to Claim 1 wherein the cross sectional area of the said restricted passage is between $^{1}/_{150}$ and $^{1}/_{75}$ of the square of the bore diameter.

3. Apparatus according to Claim 1 or 2 wherein the said feeding helices comprise a first forward feed flight for advancing the material from the feed opening through the forward feed of the resistor, and a second feed flight for receiving the material from the resistor and advancing it towards the extruder opening.

4. Apparatus according to Claim 3 wherein the pitch of the helix of the said first flight, and the diameter of the stem thereof co-operate to provide a flow passage for the material which progressively diminishes in volume in the direction of flow of the material.

5. Apparatus according to Claim 4 wherein the helix of said first flight is of constant pitch and the stem thereof increases in diameter in the direction of movement of the material.

6. Apparatus according to Claim 4 wherein the stem of said first flight is of constant diameter and the helix thereof is of progressively diminishing pitch in the direction of flow of the material.

7. Apparatus according to Claim 4 wherein the pitch of the helix of said first flight progressively decreases and the diameter of the

stem thereof progressively increases in the direction of flow of the material.

8. Apparatus according to any of Claims 3 to 7 wherein the said resistor has at least a portion of its stem of a diameter larger than the diameter of the stem of said first forward feed flight.

9. Apparatus according to Claim 8 wherein the stem diameter of the resistor further increases, in the last half full turn of the helix of the resistor.

10. Apparatus according to Claim 8 or 9 wherein the stem diameter of the resistor increases throughout its length in the direction of flow of the material.

11. Apparatus according to Claim 8, 9 or 10 wherein the maximum diameter of the resistor provides a flow passage having a depth equal to approximately $^1/_{30}$ of the diameter of the bore.

12. Apparatus according to any of Claims 3 to 11 wherein the said second feed flight has a helix of constant pitch and a stem of constant diameter.

13. Apparatus according to Claim 12 wherein the pitch of the helix is less than the minimum pitch of the helix of the first feed flight.

14. Apparatus according to any of the preceding claims provided with means for discharging from the casing volatiles which are released from the material after passing through the resistor.

15. Apparatus according to any of the preceding claims wherein the said extrusion opening is provided with a die positioned therein through which the material is forced by said one of the feed members.

16. Apparatus according to Claim 15 wherein the bore adjacent the die gradually expands to form a flared end, and the helix of the feed member expands radially to flare outwardly in close proximity to the bore.

17. Apparatus according to Claim 15 or 16 wherein the die is provided with a plurality of extruding openings and the end of the feed member is spaced from the inner face of the die a distance not more than $^1/_8$ inch and sufficient to give a running clearance therebetween, the said feed member having a surface adjacent the edge thereof which is turned in a smooth curve to join the said end of the member thereby forming a wedge-shaped clearance between the feed member and the die to force the material through the die.

18. Apparatus according to Claim 17 wherein the said extruding openings comprise a plurality of closely spaced holes extending through the die, the diameter of the holes at the outer face of the die being greater than the diameter at the inner face of the die.

19. Apparatus according to Claim 18 wherein each hole tapers outwardly in the direction of flow of material therethrough, for at least a distance of one half the length of the hole.

20. Apparatus according to Claim 19 wherein the diameter of each hole at the outer face of the die is not more than $^1/_4$ greater than the diameter of the hole at the inner face of the die.

21. Apparatus according to Claim 15 wherein the die is provided with a conical recess communicating with a slot through which the material is extruded, and the end of the said one feed member adjacent the die is formed as a tapered tip closely spaced from the wall of the said conical recess and overlapping the intersection of the slot with the recess.

22. A method of continuously mixing and processing a curable thermosetting plastic material in apparatus according to any of the preceding claims, by advancing the material through the casing from the feed opening to the extrusion opening by means of the helical feed member or members, which comprises continuously passing a blend of raw ingredients through the casing in a succession of forward feeding efforts including an initial forward feed, a following forward feed imposing a back pressure on said initial forward feed, and a further forward feed following the release of pressure at the discharge from said following forward feed so as to predetermine the relative pressures of the material at selected areas along the casing, simultaneously mixing and fusing the blend under the said relative pressures by a shearing action throughout the mass of material, and regulating the temperature of the material at each of the said successive forward feeds so as to control the curing effect and preserve the thermosetting characteristics of the material.

23. Apparatus for mixing and processing thermosetting plastic materials substantially as herein before described and illustrated with reference to the alternative forms shown in the accompanying drawings.

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779,364 COMPLETE SPECIFICATION
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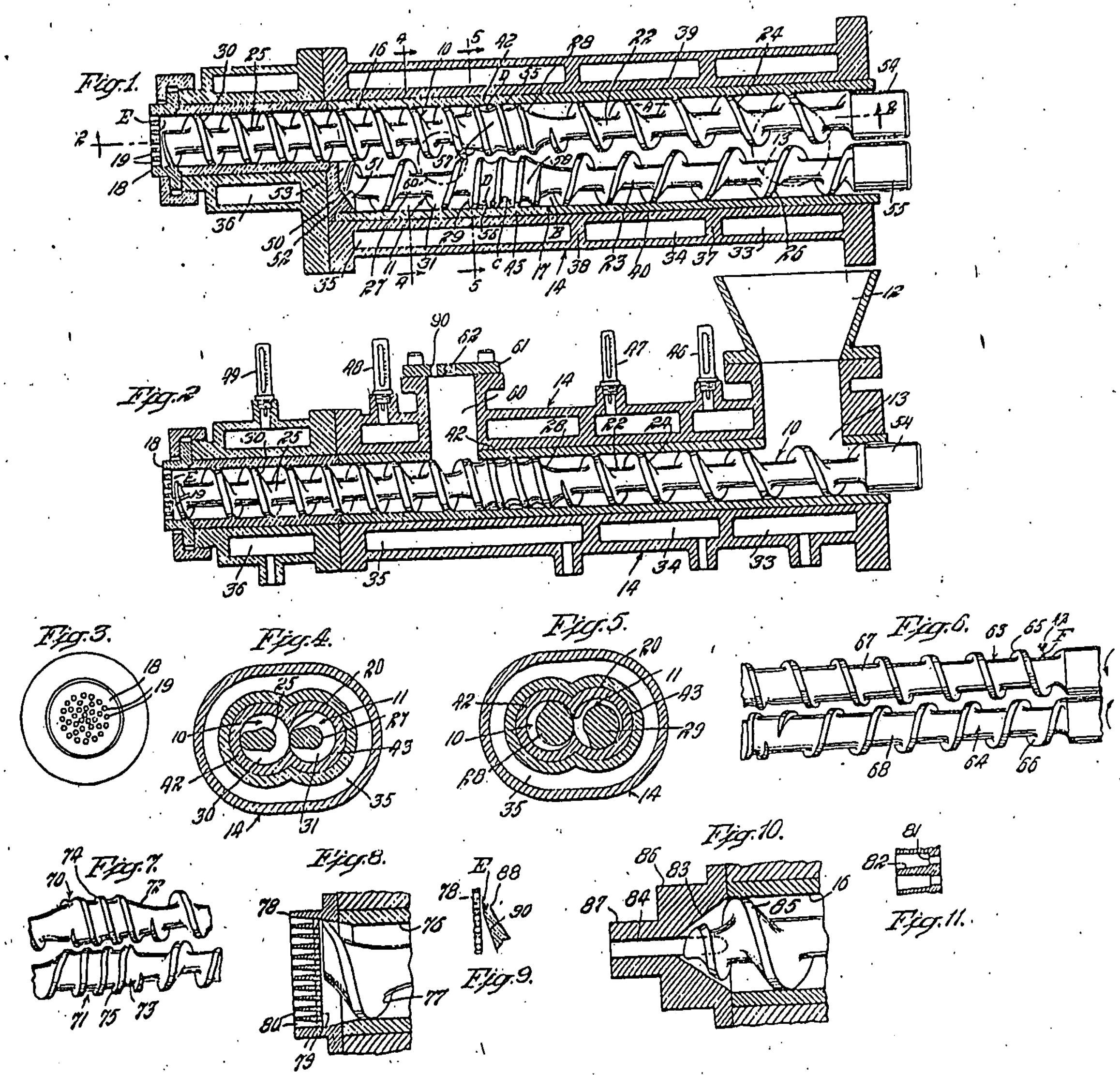


Fig.1.

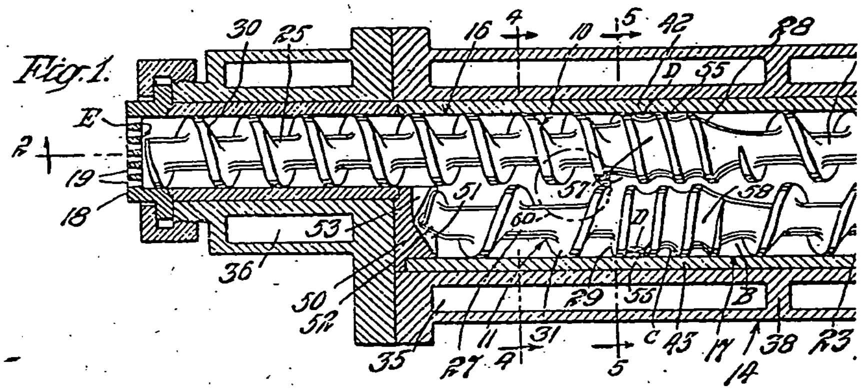


Fig.2.

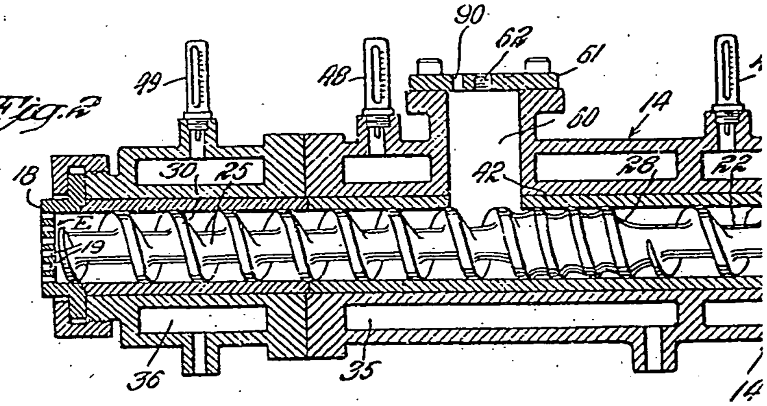


Fig.3.

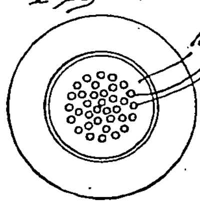


Fig.4.

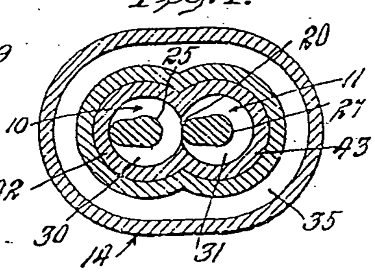


Fig.5.

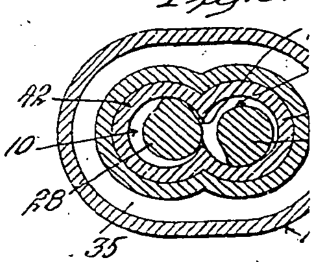


Fig.7.

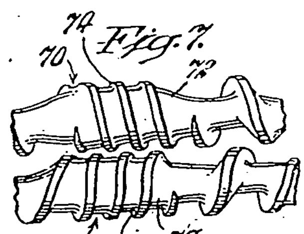
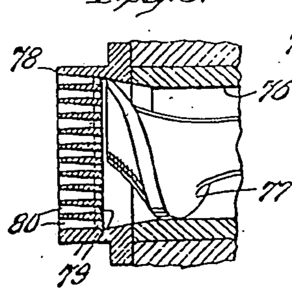


Fig.8.



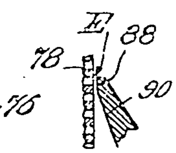


Fig.9.

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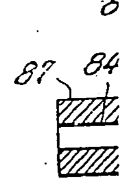

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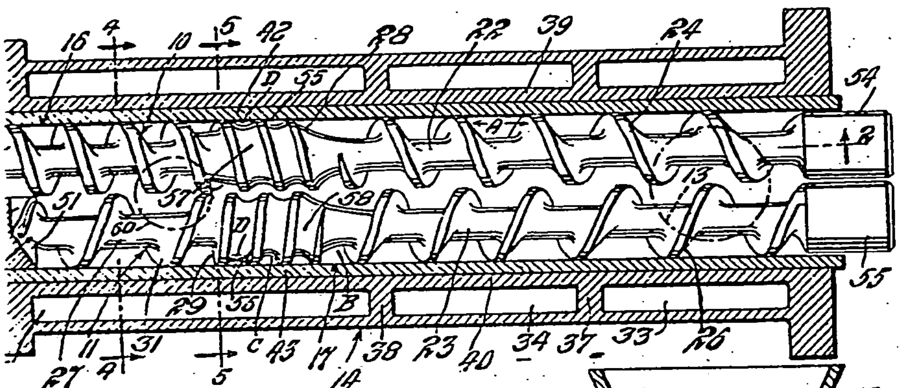
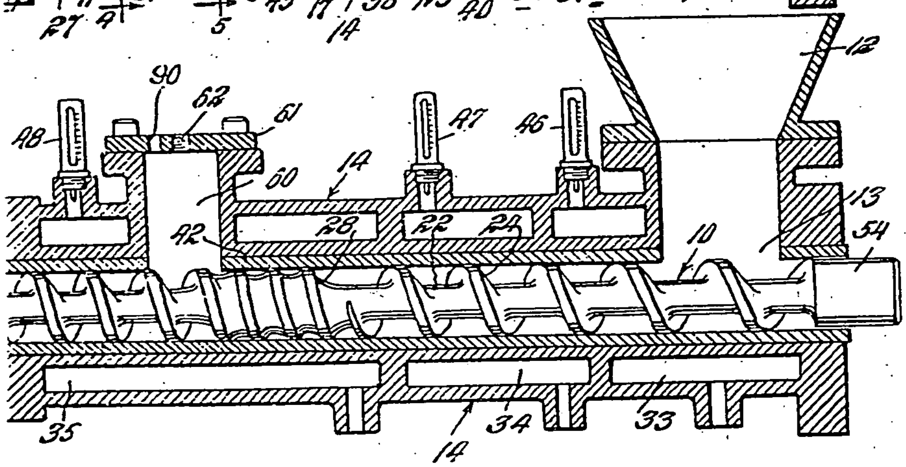




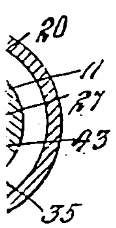


Fig.5.

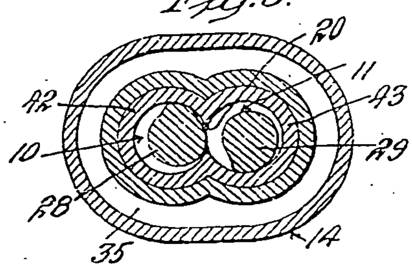
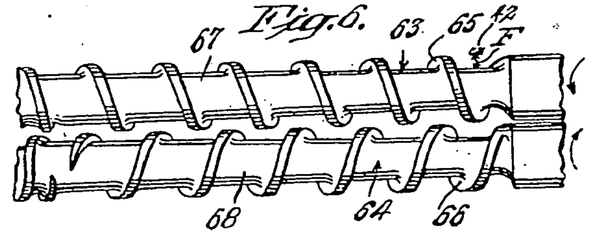
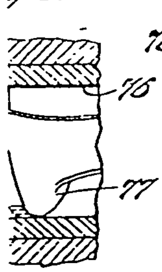


Fig.6.



-g.8.



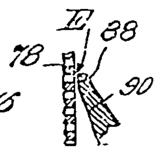
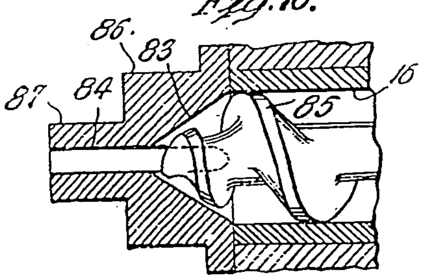


Fig.9.

Fig.10.



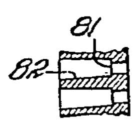


Fig.11.